Digital Elevation Model of Astoria, Oregon:
Procedures, Data Sources and Analysis

Prepared for the Pacific Marine Environmental Laboratory (PMEL) by
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Contents

List of Figures

List of Tables

Digital Elevation Model of Astoria, OR: Procedures, Data Sources and Analysis

1. Introduction

In June of 2012, the National Geophysical Data Center (NGDC), an office of the National Oceanic and Atmospheric Administration (NOAA), developed a bathymetric–topographic digital elevation model (DEM) of Astoria, OR (Figure 1). A 1/3 arc-second[1] DEM referenced to mean high water (MHW) was carefully developed and evaluated. The 1/3 arc-second MHW DEM will be used as input for the Method of Splitting Tsunami (MOST) model developed by the Pacific Marine Environmental Laboratory (PMEL) NOAA Center for Tsunami Research (http://nctr.pmel.noaa.gov/) to simulate tsunami generation, propagation and inundation. The DEM was generated from diverse digital datasets in the region (grid boundary and sources shown in Figures 2 and 3). The DEM will be used for tsunami inundation modeling, as part of the tsunami forecast system Short-term Inundation Forecasting for Tsunamis (SIFT) currently being developed by PMEL for the NOAA Tsunami Warning Centers. This report provides a summary of the data sources and methodology used in developing the Astoria DEM.

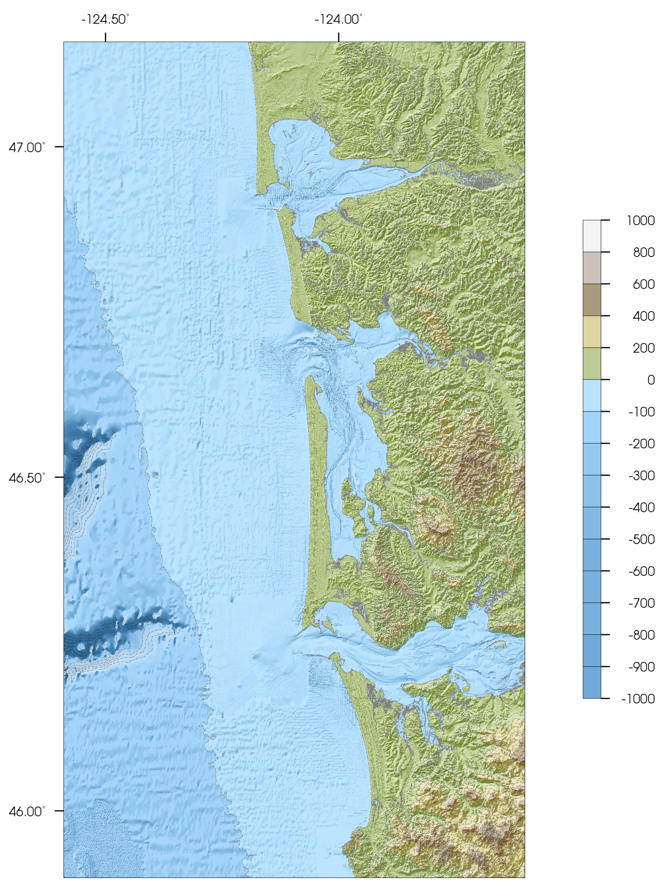

Figure 1. *Shaded relief image of the Astoria DEM.*

[1]The Astoria, OR DEM is built upon a grid of cells that are square in geographic coordinates (latitude and longitude), however, the cells are not square when converted to projected coordinate systems, such as UTM zones (in meters). At the latitude of Astoria, OR, 1/3 arc-second of latitude is equivalent to 10.29556 meters; 1/3 arc-second of longitude equals 7.95 meters

2. STUDY AREA

The Astoria DEM covers the region surrounding Astoria, Oregon (Figure 2), including the southern coastal portions of Washington State.

Table 1. Specifications for the Astoria DEM

Grid Area	Astoria, OR
Coverage Area	-124.59 °, -123.60 °, 45.9 °, 47.16 °
Coordinate System	Geographic decimal degrees
Horizontal Datum	North American Datum of 1983 (NAD 83)
Vertical Datum	MHW
Vertical Units	Meters
Grid Spacing	1/3 arc-second
Grid Format	ESRI Arc ASCII grid

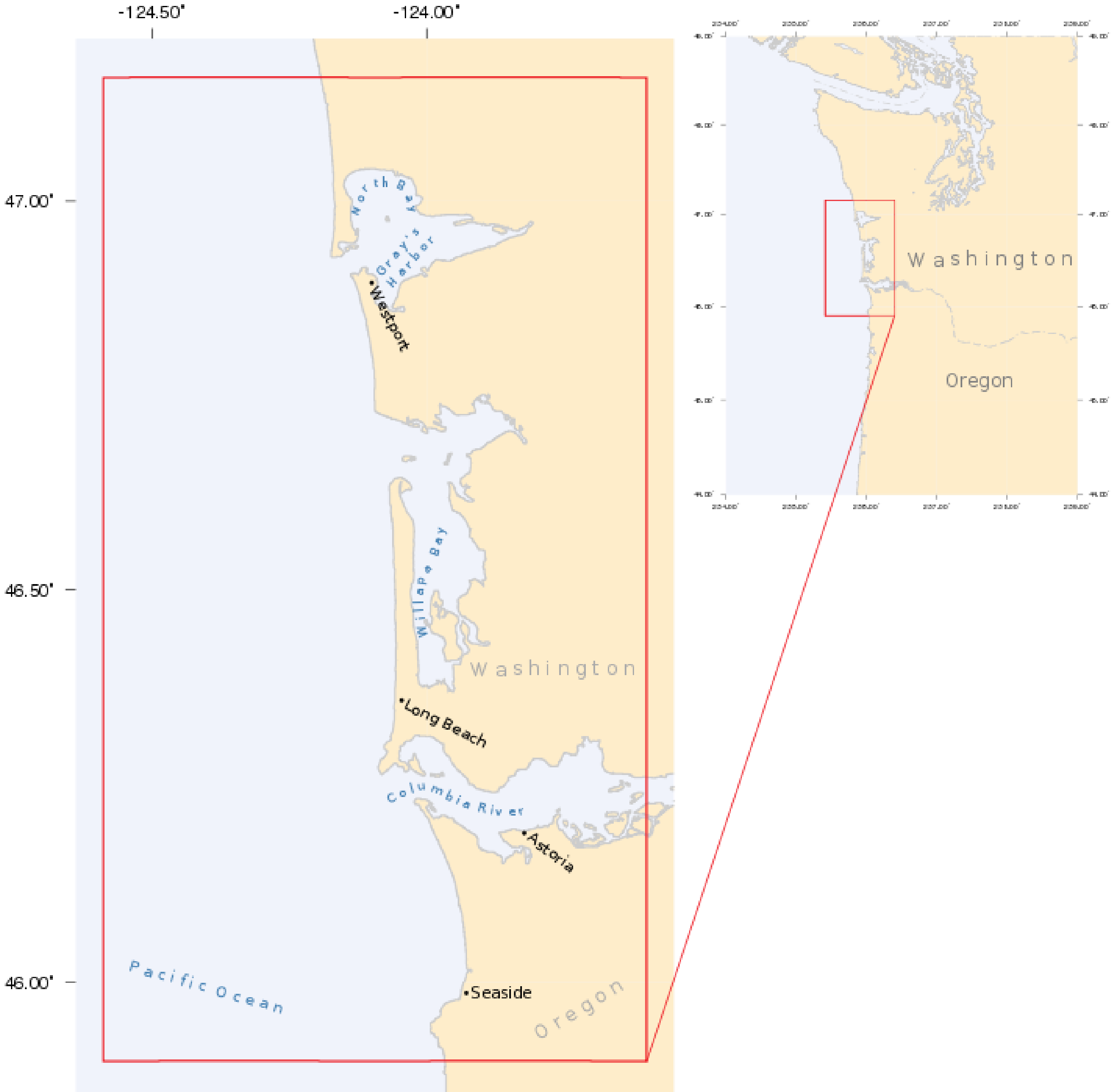

Figure 2. *Overview map illustrating the extents of the Astoria DEM*

3. Source Elevation Data

The best available digital data were obtained by NGDC from several U.S. federal agencies: NOAA's NGDC and the United States Geological Survey (USGS) and the United States Army Corps of Engineers (USACE). Data were gathered in an area slightly larger (∼5%) than the DEM extents. This data 'buffer' ensures that gridding occurs across rather than along the DEM boundaries to prevent edge effects. Data processing and evaluation, as well as DEM assembly and assessment are described in the following subsections.

Figure 3. *Data sources in the Astoria region.*

3.1 Data Sources And Processing

Coastline, bathymetric, and topographic digital datasets (Tables 2, 3, and 4; Figure 3) were obtained by NGDC and shifted to common horizontal and vertical datums: NAD 83 geographic[2] and MHW, respectively. The datasets were assessed to determine data quality and were manually edited where needed. Vertical datum transformations to MHW were accomplished using a conversion grid developed using NOAA's *VDatum* software package (Section 3.2.2).

3.1.1 Coastline

Coastline datasets of the Astoria region were obtained from a variety of sources. The main dataset used in developing a combined, detailed coastline was the NOAA Office of Coast Survey (OCS) digitized vector coastline (Table 2). This dataset provided a medium resolution coastline of the Astoria region.

The OCS coastline was edited by NGDC using ESRI World Imagery to better represent the coastline immediately sourrounding bays and inlets and to ensure the resolution of the breakwaters in the region, which were not adequately represented in other data sources.

Table 2. Shoreline datasets used in compiling the Astoria DEM

Source	***Year***	***Data Type***	***Spatial Resolution***	***Original Horizontal Datum/Coordinate System***	***Original Vertical Coordinate System***	***URL***
OCS	2011	Digitized vector Coastline	Not defined	World Geodetic System (WGS) 84 geographic	MHW	N/A
NGDC	2011	Digitized vector Coastline	Not defined	World Geodetic System (WGS) 84 geographic	MHW	N/A

[2]The horizontal difference between the North American Datum of 1983 (NAD 83) and World Geodetic System of 1984 (WGS 84) geographic horizontal datums is approximately one meter across the contiguous U.S., which is significantly less than the cell size of the DEM. Many GIS applications treat the two datums as identical, so do not actually transform data between them, and the error introduced by not converting between the datums is insignificant for our purposes. NAD 83 is restricted to North America, while WGS 84 is a global datum. As tsunamis may originate most anywhere around the world, tsunami modelers require a global datum, such as WGS 84 geographic, for their DEMs so that they can model the waves passage across ocean basins. This DEM is identified as having a WGS 84 geographic horizontal datum even though the underlying elevation data were typically transformed to NAD 83 geographic. At the scale of the DEM, WGS 84 and NAD 83 geographic are identical and may be used interchangeably.

3.1.2 Bathymetry

Bathymetric datasets available in the Astoria region included 28 National Ocean Survey (NOS) high-resolution surveys in Bathymetric Attributed Grid (BAG) format, and 77 NOAA NOS Hydro surveys (Table 3; Figure 3). NGDC evaluated but did not use the OCS Electronic Nautical Charts (ENCs) soundings or the NGDC multibeam bathymetry due to conflicts with the other bathymetric surveys.

Table 3. Bathymetric datasets used in compiling the Astoria DEM

Source	*Year*	*Data Type*	*Spatial Resolution*	*Original Horizontal Datum/Coordinate System*	*Original Vertical Coordinate System*	*URL*
NOS BAG	2004 - 2010	Soundings	N/A	NAD 83 geographic	mean lower low water (MLLW)	N/A
NOS Hydro	1851 - 2004	Soundings	N/A	NAD 83 geographic	MLLW	http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html

1) NOS/BAG Hydrographic Surveys

A total of 28 NOS high-resolution hydrographic surveys, in BAG format, were conducted between 2008 and 2009 and were available for use in the development of the Astoria DEM (Figure 3). The data were vertically referenced to MLLW and horizontally referenced to NAD 83 geographic and were transformed to MHW using a conversion grid (Section 3.2.2).

2) NOS Hydrographic Surveys

A total of 77 NOS hydrographic surveys were available for use in the development of the Astoria DEM (Figure 3). The data were vertically referenced to MLLW and horizontally referenced to NAD 83 geographic and were transformed to MHW using a conversion grid (Section 3.2.2).

3.1.3 Topography

The topographic datasets used to build the Astoria DEM were the US Geological Society (USGS) National Elevation Dataset (NED) 1/9 arc-second and 1/3 arc-second DEMs, and the United States Army Corps of Engineers (USACE) lidar of the Columbia River (Table 4; Figure 3).

Table 4. Topographic dataset used in compiling the Astoria DEM

Source	*Year*	*Data Type*	*Spatial Resolution*	*Original Horizontal Datum/Coordinate System*	*Original Vertical Coordinate System*	*URL*
USGS	2011	Bare-earth 1/3 Arc-Second DEM	5 - 10 meters	WGS 84 geographic	NAVD 88	N/A
USGS	2011	Bare-earth DEM 1/9 Arc-Second DEM	1 - 6 meters	WGS 84 geographic	NAVD 88	N/A
USACE	2011	lidar	1 - 6 meters	WGS 84 geographic	NAVD 88	N/A

1) USGS NED 1/9 arc-second DEM

The USGS NED provides 1/9 arc-second DEMs of portions of the Astoria project area. Data are in NAD 83 geographic coordinates and NAVD 88 vertical datum (meters), and are available for download as raster DEMs. The bare-earth elevations have a vertical accuracy of +/- 1 to 6 meters depending on source data resolution. See the USGS Seamless web site for specific source information (http://seamless.usgs.gov). The dataset was derived from USGS quadrangle maps and aerial photographs based on topographic surveys; it has been revised using data collected in 1999. The NED DEMs were transformed to NAD 83 and MHW using *proj4* and a conversion grid, respectively (Section 3.2.2). The gridded data were evaluated and positive elevations over open water were removed by clipping the data to the coastline using *GDAL* and *Python*.

2) USGS NED 1/3 arc-second DEM

The USGS NED provides complete 1/3 arc-second coverage of the Astoria project area. Data are in NAD 83 geographic coordinates and NAVD 88 vertical datum (meters), and are available for download as raster DEMs. The bare-earth elevations have a vertical accuracy of +/- 7 to 15 meters depending on source data resolution. See the USGS Seamless web site for specific source information (http://seamless.usgs.gov). The dataset was derived from USGS quadrangle maps and aerial photographs based on topographic surveys; it has been revised using data collected in 1999. The NED DEMs were transformed to NAD 83 and MHW using *proj4* and a conversion grid, respectively (Section 3.2.2). The gridded data were evaluated and positive elevations over open water were removed by clipping the data to the coastline using *GDAL* and *Python*.

3) USACE Columbia River Lidar

The Columbia River Light Detection and Ranging (LiDAR) survey project was a collaborative effort to develop detailed high density LiDAR terrain data for the US Army Corps of Engineers (USACE). The LiDAR will be used to support hydraulic modeling work associated with proposed 2014 Columbia River treaty negotiations. The dataset encompasses approximately 2836 square miles of territory in portions of Oregon, Washington, Idaho and Montana within the Columbia River drainage. This survey was under the jurisdiction of three Corps districts: Portland (CENWP), Seattle (CENWS), and Walla Walla (CENWW). CENWP was the project lead and primary contracting organization. The lidar data was transformed to NAD 83 and MHW using *proj4* and a conversion grid, respectively (Section 3.2.2). The resulting data were converted to xyz data using *GDAL*.

3.2 Establishing Common Datums

3.2.1 Vertical Datum Transformations

Datasets used in the compilation and evaluation of the Astoria DEM were originally referenced to MLLW or NAVD 88. All datasets were transformed to MHW using a conversion grid developed using NOAA's *VDatum* software. (Section 3.2.2; Figs. 4 & 5).

- **Bathymetric Data:** All hydrographic surveys were transformed from MLLW or NAVD 88 to MHW using a conversion grid.
- **Topographic Data:** All topographic datasets used in the compilation of the Astoria DEM originated in NAD 88 vertical datum and were transformed to MHW using a conversion grid.

3.2.2 Developing the conversion grid

Using extents slightly larger ($\sim$5%) than the Astoria project area, an initial *xyz* file was created that contained the coordinates of the four bounding vertices and midpoint of the larger extents. The elevation value at each of the points was set to zero. The GMT command 'surface' applied a tension spline to interpolate cell values making a zero-value 3 arc-second grid. This "zero-grid" was then converted to an intermediate *xyz* file using the GMT command 'grd2xyz'. Conversion values from NAVD 88 to MHW and MLLW to MHW at each *xyz* point were generated using *VDatum* and the null values were removed.

The median-averaged *xyz* file was then interpolated with the GMT command 'surface' to create the 1/3 arc-second 'NAVD 88 to MHW' and 'MLLW to MHW' conversion grids with the extents of the buffered Fort Bragg project area, representing the differences between the datums onshore to the DEM extents (Figures 4 & 5).

3.2.3 Assessing accuracy of conversion grid

The conversion grids were assessed using the NOS survey data. For testing of this methodology, the NOS hydrographic survey data were transformed from MLLW to NAVD 88 using *VDatum*. The resultant *xyz* files were filtered to remove any null values and then were merged together to form a single *xyz* file of the NOS hydrographic survey data with a vertical datum of NAVD 88. A second *xyz* file of NOS data was created with a vertical datum of MHW using the same method. Elevation differences between the MHW and NAVD 88 *xyz* files were computed. The same method was used to assess the 'MLLW to MHW' conversion grid.

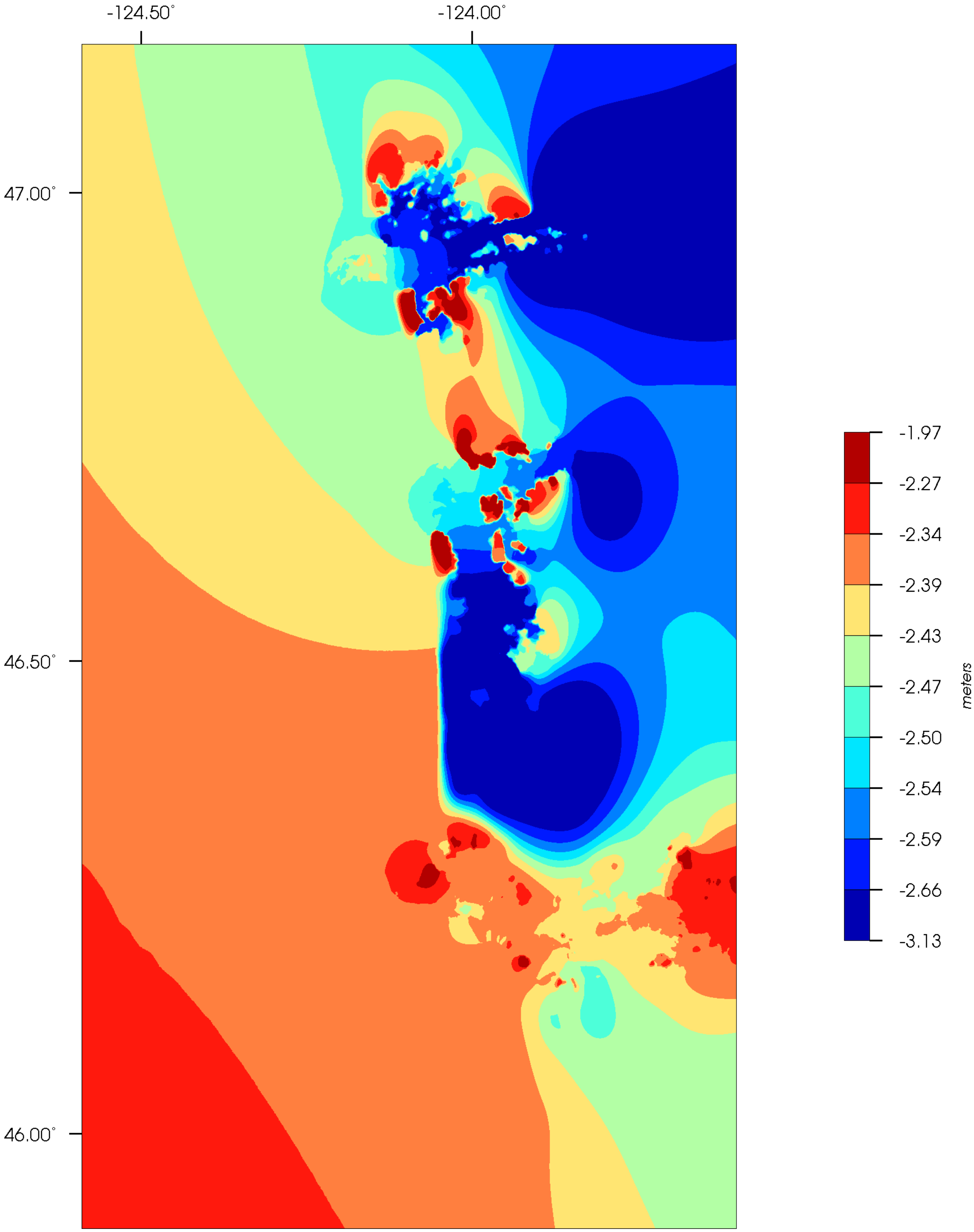

Figure 4. *MLLW to MHW Conversion Grid of the Astoria DEM. Values equal the difference between MLLW and MHW.*

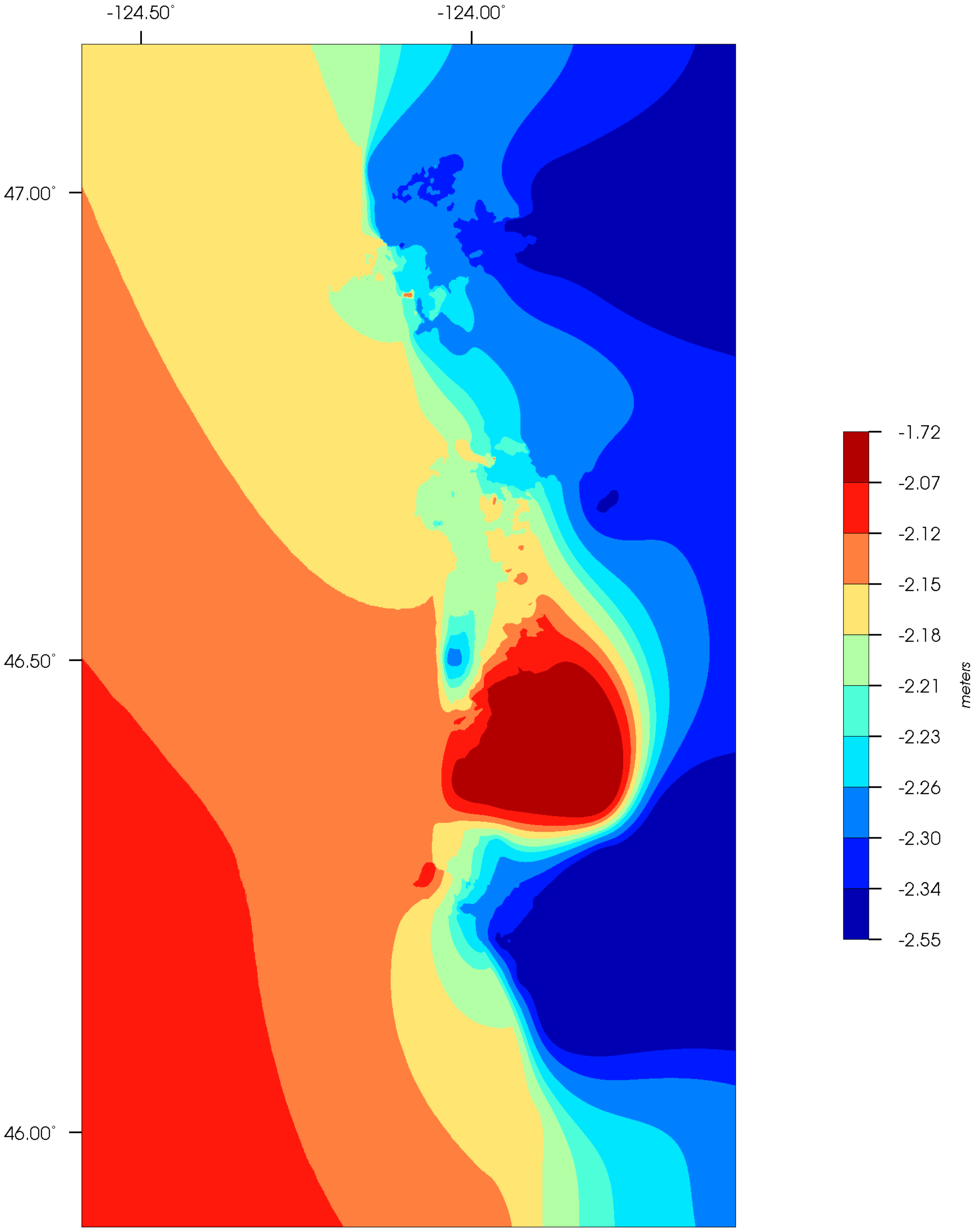

Figure 5. *NAVD 88 to MHW Conversion Grid of the Astoria DEM. Values equal the difference between NAVD 88 and MHW.*

3.2.4 Horizontal Datum Transformations

Datasets used to build the Astoria DEM were downloaded or received referenced to WGS 84 geographic or NAD 83 geographic horizontal datums. The relationship transformational equations between these horizontal datums are well established. Data were transformed to a horizontal datum of NAD 83 geographic using *Proj4*.[3]

3.3 Verifying consistency between datasets

After horizontal and vertical transformations were applied, the ascii *xyz* files were reviewed for consistency between datasets. Problems and errors were identified and resolved before proceeding with subsequent gridding steps.

[3] *Proj4* is a free standard Unix filter function which converts geographic longitude and latitude coordinates into cartesian coordinates, $(\lambda, \phi) \rightarrow (x, y)$, by means of a wide variety of cartographic projection functions. http://trac.osgeo.org/proj/

4. DEM DEVELOPMENT

4.1 Smoothing of bathymetric data

The NGDC NOS hydrographic survey data are generally sparse relative to the resolution of the 1/3 arc-second Astoria DEM. This is especially true for deep water surveys in the Pacific and shallow water surveys in bays where data have point spacing up to 350 meters apart. In order to reduce artifacts created in the DEM by the low-resolution bathymetric datasets and to provide effective interpolation in the deep water and into the coastal zone, a 1 arc-second pre-surface bathymetric grid was generated using Generic Mapping Tools (*GMT*)[4]. The coastline elevation value was set at zero meters to ensure a bathymetric surface below zero in areas where data are sparse or non-existent.

The point data were median-averaged using the *GMT* command "blockmedian" to create a 1 arc-second grid 0.05 degrees (∼5%) larger than the Astoria DEM gridding region. The *GMT* command "surface" was then used to apply a tight spline tension to interpolate elevations for cells without data values. The *GMT* grid created by 'surface' was converted to an *ESRI* Arc ASCII grid file, and clipped to the final coastline (to eliminate data interpolation onto land areas) using *GDAL* and *Python*. The resulting surface was exported as an *xyz* file for use in the final gridding process (Table 5).

4.2 Building the MHW DEM

MB-System[5] was used to create the 1/3 arc-second Astoria MHW DEM. The MB-System command "mbgrid" was used to apply a tight spline tension to the *xyz* data, and interpolate values for cells without data. The data hierarchy used in the "mbgrid" gridding algorithm, as relative gridding weights, is listed in Table 5. The resulting binary grid was converted to an Arc ASCII grid using the *MB-System* tool "mbm_grd2arc" to create the final 1/3 arc-second Astoria MHW DEM. Figure 6 illustrates cells in the DEM that have interpolated values versus data contributing to the cell value.

[4] *GMT* is an open source collection of ∼60 tools for manipulating geographic and Cartesian data sets (including filtering, trend fitting, gridding, projecting, etc.) and producing Encapsulated PostScript File (EPS) illustrations ranging from simple x-y plots via contour maps to artificially illuminated surfaces and 3-D perspective views. *GMT* supports ∼30 map projections and transformations and comes with support data such as GSHHS coastlines, rivers, and political boundaries. *GMT* is developed and maintained by Paul Wessel and Walter H. F. Smith with help from a global set of volunteers, and is supported by the National Science Foundation. It is released under the GNU General Public License. URL: http://gmt.soest.hawaii.edu/ [Extracted from *GMT* web site.]

[5] MB-System is an open source software package for the processing and display of bathymetry and backscatter imagery data derived from multibeam, interferometry, and sidescan sonars. The source code for MB-System is freely available (for free) by anonymous ftp (point and access through these web pages). A complete description is provided in web pages accessed through the web site. MB-System was originally developed at the Lamont-Doherty Earth Observatory of Columbia University (L-DEO) and is now a collaborative effort between the Monterey Bay Aquarium Research Institute (MBARI) and L-DEO. The National Science Foundation has provided the primary support for MB-System development since 1993. The Packard Foundation has provided significant support through MBARI since 1998. Additional support has derived from SeaBeam Instruments (1994–1997), NOAA (2002–2004), and others. URL: http://www.ldeo.columbia.edu/res/pi/MB-System/ [Extracted from MB-System web site.]

Table 5. Data hierarchy used to assign gridding weight in MB-System

Dataset	***Relative Gridding Weight***
USACE Columbia River Lidar	50
USGS NED 1/9	20
NOS BAG	20
USGS NED 1/3	10
NOS Hydro	10
Pre-surfaced bathymetric grid	1

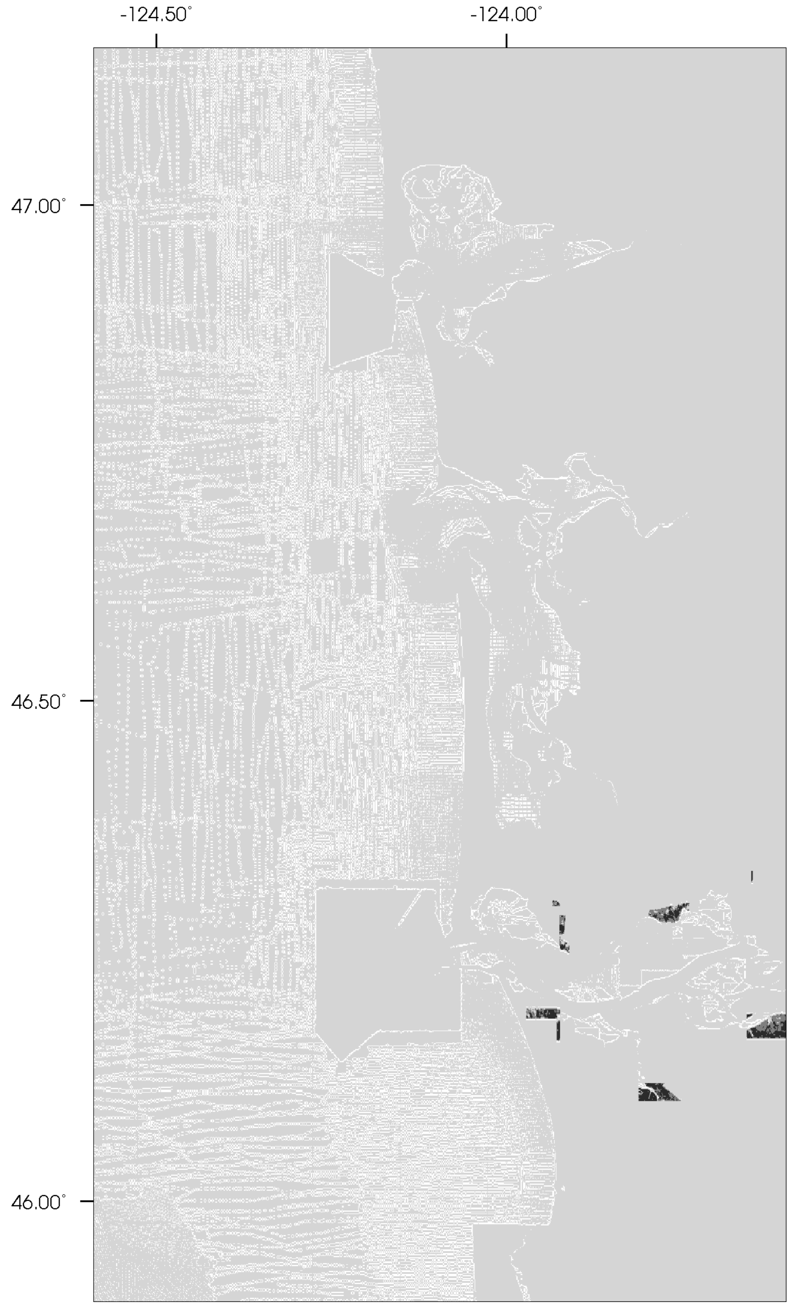

Figure 6. *Data density of the Astoria gridding region.*

4.3 Quality Assessment of the structured DEM

4.3.1 Horizontal accuracy

The horizontal accuracy of topographic and bathymetric features in the Astoria DEM is dependent upon the datasets used to determine corresponding DEM cell values and the cell size of the DEM, making the highest accuracy possible 1/3 arc-second (about 10 meters). Bathymetric features are resolved only to within a few tens of meters in deep-water areas. Shallow, near-coastal regions, rivers, and harbor surveys have an accuracy approaching that of sub aerial topographic features. Positional accuracy is limited by the sparseness of deep-water soundings and by the morphologic change that occurs in this dynamic region.

4.3.2 Vertical accuracy

Vertical accuracy of the Astoria DEM is also highly dependent upon the source datasets contributing to DEM cell values. Topographic NED data have an estimated accuracy of 7 - 20 meters. Bathymetric areas have an estimated accuracy of between 0.1 meters and 5% of water depth.

4.3.3 Slope maps and 3D perspectives

GMT was used to generate a slope grid from the Astoria DEM to allow for visual inspection and identification of artificial slopes along boundaries between datasets (Figure 7). The DEM was transformed to projected coordinates (horizontal units in meters) using *GMT* for derivation of the slope grid; equivalent horizontal and vertical units are required for effective slope analysis. Analysis of preliminary grids revealed suspect data points, which were corrected before recompiling the DEM. Figure 8 shows a perspective view image of the 1/3 arc-second Astoria DEM in its final version.

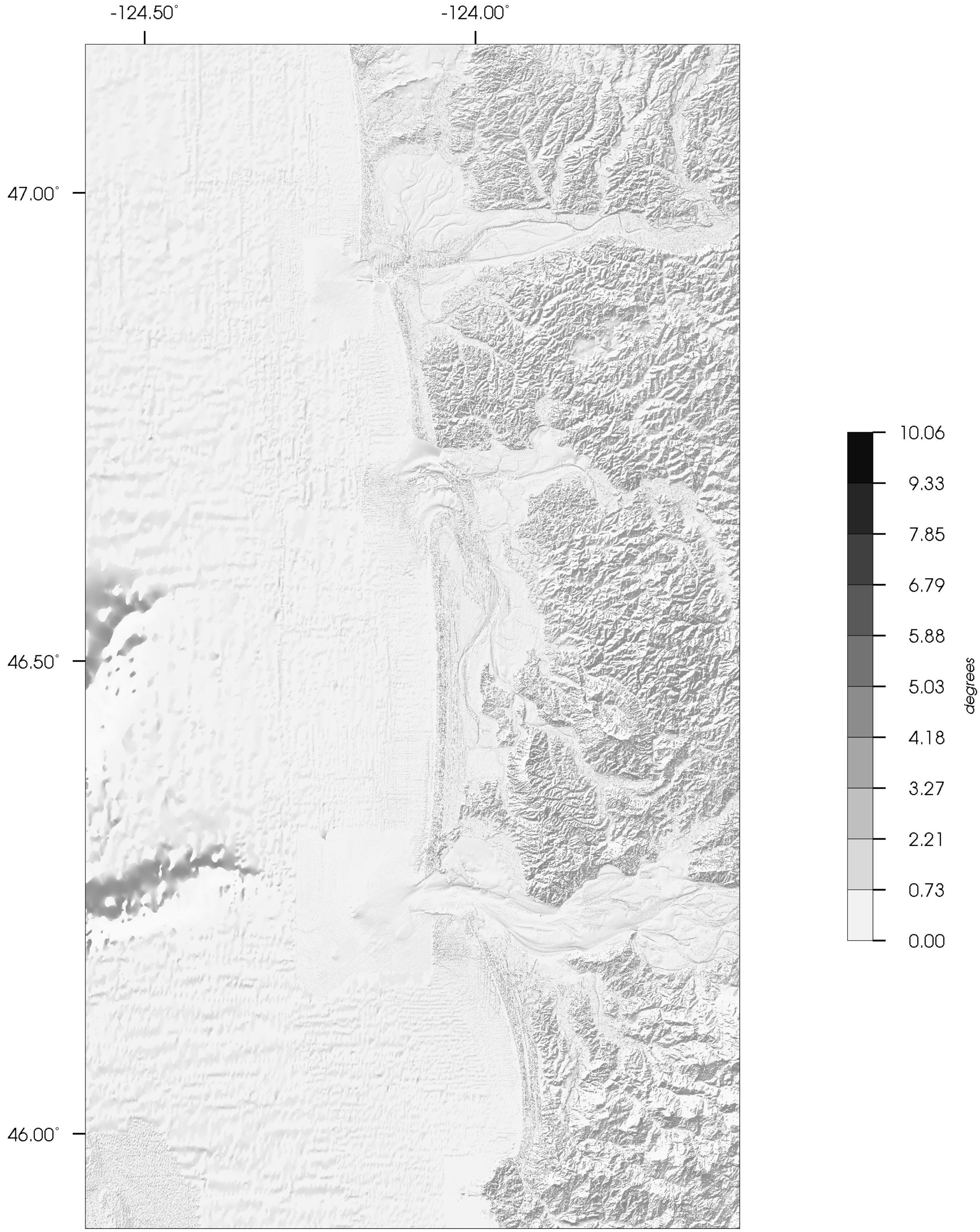

Figure 7. *Slope map of the Astoria DEM*

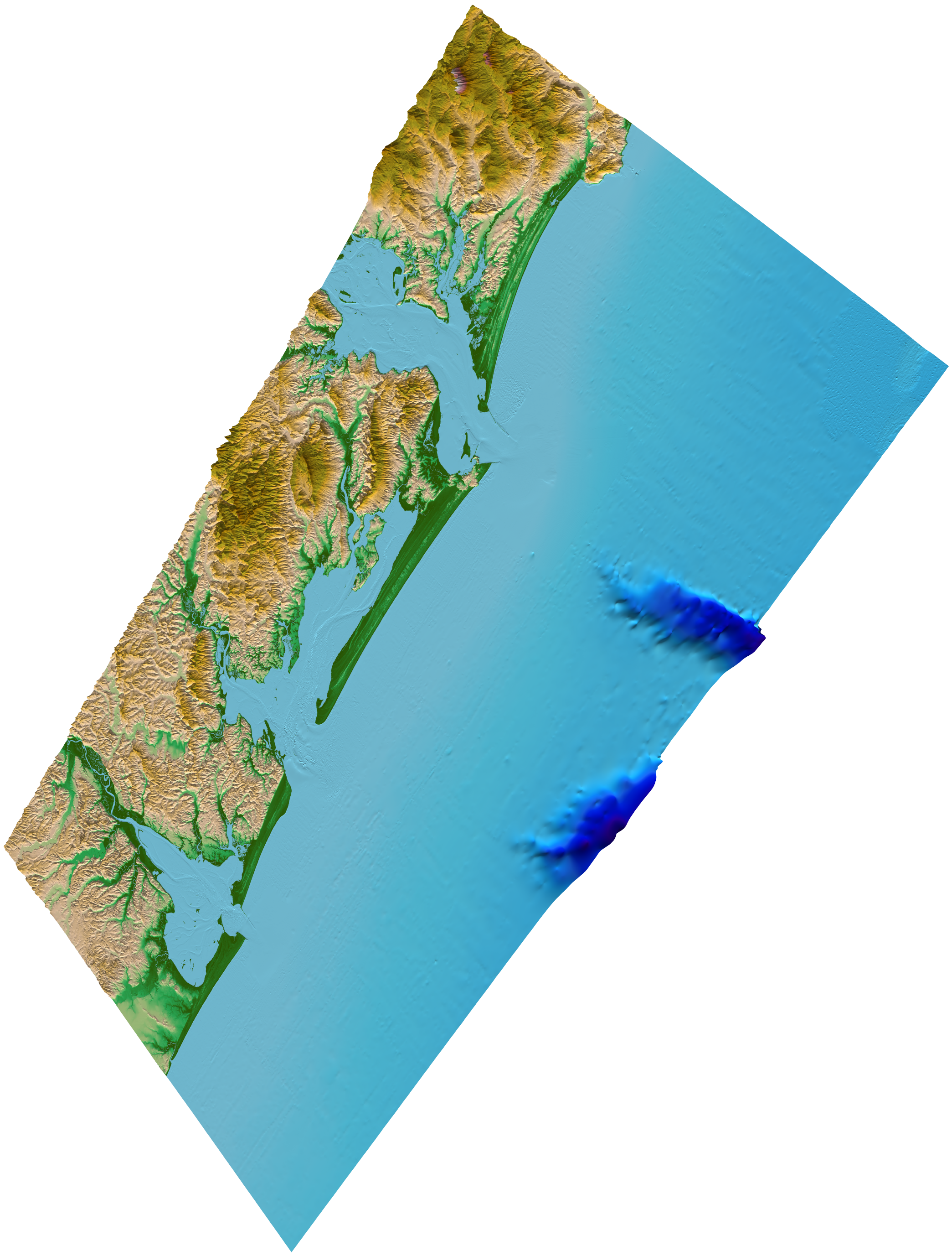

Figure 8. *Perspective view from the southwest of the Astoria DEM.*

5. Summary and Conclusions

A bathymetric–topographic structured digital elevation model of the Astoria, Oregon region, with cell spacing of 1/3 arc-second, and a vertical datum of MHW was developed by NGDC for PMEL for use in tsunami generation, propogation and inundation simulations.

Recommendations to improve the Astoria DEM, based on NGDC's research and analysis, are listed below:

- Conduct publically available lidar surveys of all topographic regions.
- Conduct publically available high-resolution surveys of all harbors and bays.

6. Acknowledgements

The creation of the Astoria DEM was funded by NOAA PMEL. The authors thank Marie Eble, Lindsey Wright and Vasily Titov (PMEL).

7. References

Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A, 2003. Federal Emergency Management Agency, Flood Hazard Mapping Program.

Taylor et al., Digital Elevation Models of Astoria, OR: Procedures, Data Sources and Analysis. National Geophysical Data Center.

8. Data Processing Software

ArcGIS 10, developed and liscensed by ESRI, Redlands, California, http://www.esri.com

ESRI World Imagery - ESRI ArcGIS Resource Centers, http://www.esri.com

GEODAS v. 5 - Geophysical Data System, free software developed and maintained by Dan Metzger, NOAA National Geophysical Data Center, http://www.ngdc.noaa.gov/mgg/geodas

GMT v. 4.1.4 - Generic Mapping Tools, free software developed and maintained by Paul Wessel and Walter Smith, funded by the National Science Foundation, http://gmt.soest.hawaii.edu

MB-System v. 5.1.0, free software developed and maintained by David W. Caress and Dale N. Chayes, funded by the National Science Foundation, http://www.ldeo.columbia.edu/res/pi/MB-System

Quick Terrain Modeler v. 6.0.1, lidar processing software developed by John Hopkins University's Applied Physics Laboratory (APL) and maintained and licensed by Applied Imagery, http://www.appliedimagery.com

GDAL v. 1.8.0 Geographic Data Abstraction Library is a translator library maintained by Frank Warmerdam, http://gdal.org

Proj4 v. 4.7.0 free software developed by Gerald Evenden and maintained by Frank Warmerdam, http://trac.osgeo.org/proj/

A. SOURCE BATHYMETRY DATA

Table A-1. NOS Hydrographic datasets used in building the Astoria DEM

Survey ID	***Year***	***Scale/Vertical Accuracy***	***Original Vertical Datum***	***Provided Horizontal Datum***
Survey	Resolution	Date	Horizontal Datum	Vertical Datum
B00115	1987-10-09	N/A	North American Datum 1983	MLLW
B00116	1987-10-12	N/A	North American Datum 1983	MLLW
F00430	1997-04-08	20000	North American Datum 1983	MLLW
F00486	2002-10-16	5000	North American Datum 1983	MLLW
H00250	1851-12-31	20000	North American Datum 1983	MLLW
H00335	1852-12-31	20000	North American Datum 1983	MLLW
H00809	1862-12-31	20000	North American Datum 1983	MLLW
H01019	1868-12-31	20000	North American Datum 1983	MLLW
H01378	1877-12-31	20000	North American Datum 1983	MLLW
H01379	1877-12-31	20000	North American Datum 1983	MLLW

Table A-1 – Continued

Survey ID	***Year***	***Scale/Vertical Accuracy***	***Original Vertical Datum***	***Provided Horizontal Datum***
H01589A	1891-12-31	20000	North American Datum 1983	MLLW
H01800	1887-12-31	40000	North American Datum 1983	MLLW
H02103	1891-12-31	10000	North American Datum 1983	MLLW
H03297	1911-12-31	20000	North American Datum 1983	MLLW
H04363	1924-12-31	20000	North American Datum 1983	MLLW
H04611	1926-12-31	20000	North American Datum 1983	MLLW
H04612	1926-12-31	20000	North American Datum 1983	MLLW
H04618	1926-12-31	20000	North American Datum 1983	MLLW
H04619	1926-12-31	20000	North American Datum 1983	MLLW
H04620	1926-12-31	20000	North American Datum 1983	MLLW
H04621	1926-12-31	20000	North American Datum 1983	MLLW

Table A-1 – Continued

Survey ID	***Year***	***Scale/Vertical Accuracy***	***Original Vertical Datum***	***Provided Horizontal Datum***
H04633A	1926-12-31	120000	North American Datum 1983	MLLW
H04634	1927-12-31	40000	North American Datum 1983	MLLW
H04635	1926-12-31	40000	North American Datum 1983	MLLW
H04636	1926-12-31	80000	North American Datum 1983	MLLW
H04639	1926-12-31	120000	North American Datum 1983	MLLW
H04658	1928-12-31	15000	North American Datum 1983	MLLW
H04710	1927-12-31	20000	North American Datum 1983	MLLW
H04715	1927-12-31	20000	North American Datum 1983	MLLW
H04728	1927-12-31	40000	North American Datum 1983	MLLW
H04729	1927-12-31	40000	North American Datum 1983	MLLW
H04735	1927-12-31	80000	North American Datum 1983	MLLW

Table A-1 – Continued

Survey ID	*Year*	*Scale/Vertical Accuracy*	*Original Vertical Datum*	*Provided Horizontal Datum*
H05927	1935-12-31	80000	North American Datum 1983	MLLW
H05928	1935-12-31	80000	North American Datum 1983	MLLW
H05975	1935-12-31	80000	North American Datum 1983	MLLW
H05976	1935-12-31	80000	North American Datum 1983	MLLW
H06178	1936-12-31	80000	North American Datum 1983	MLLW
H06179	1936-12-31	10000	North American Datum 1983	MLLW
H06180	1937-12-31	10000	North American Datum 1983	MLLW
H06181	1937-12-31	10000	North American Datum 1983	MLLW
H06237	1937-12-31	10000	North American Datum 1983	MLLW
H06514	1939-12-31	10000	North American Datum 1983	MLLW
H06515	1939-12-31	10000	North American Datum 1983	MLLW

Table A-1 – Continued

Survey ID	***Year***	***Scale/Vertical Accuracy***	***Original Vertical Datum***	***Provided Horizontal Datum***
H06516	1939-12-31	10000	North American Datum 1983	MLLW
H06517	1939-12-31	10000	North American Datum 1983	MLLW
H06518	1939-12-31	10000	North American Datum 1983	MLLW
H06519	1939-12-31	10000	North American Datum 1983	MLLW
H06520	1939-12-31	10000	North American Datum 1983	MLLW
H06521	1939-12-31	10000	North American Datum 1983	MLLW
H06646	1940-12-31	10000	North American Datum 1983	MLLW
H06647	1940-12-31	10000	North American Datum 1983	MLLW
H06665	1941-12-31	10000	North American Datum 1983	MLLW
H07178	1947-12-31	10000	North American Datum 1983	MLLW
H07179	1947-12-31	5000	North American Datum 1983	MLLW

Table A-1 – Continued

Survey ID	***Year***	***Scale/Vertical Accuracy***	***Original Vertical Datum***	***Provided Horizontal Datum***
H07180	1947-12-31	5000	North American Datum 1983	MLLW
H07816	1950-12-31	10000	North American Datum 1983	MLLW
H07817	1950-12-31	10000	North American Datum 1983	MLLW
H07940	1951-12-31	10000	North American Datum 1983	MLLW
H08136	1954-10-29	10000	North American Datum 1927	MLLW
H08137	1954-10-22	10000	North American Datum 1927	MLLW
H08138	1954-10-01	15000	North American Datum 1927	MLLW
H08250	1956-08-16	10000	North American Datum 1927	MLLW
H08251	1956-08-21	10000	North American Datum 1927	MLLW
H08252	1955-10-21	20000	North American Datum 1927	MLLW
H08292	1956-08-29	10000	North American Datum 1927	MLLW

Table A-1 – Continued

Survey ID	***Year***	***Scale/Vertical Accuracy***	***Original Vertical Datum***	***Provided Horizontal Datum***
H08293	1956-09-25	10000	North American Datum 1927	MLLW
H08335	1954-10-19	10000	North American Datum 1927	MLLW
H08416	1958-08-14	20000	North American Datum 1927	MLLW
H08417	1958-08-14	20000	North American Datum 1927	MLLW
H08419	1958-08-19	10000	North American Datum 1927	MLLW
H08420	1958-09-16	10000	North American Datum 1927	MLLW
H08423	1958-09-04	10000	North American Datum 1927	MLLW
H08436	1958-09-03	5000	North American Datum 1927	MLLW
H11282	2005-07-06	10000	North American Datum 1983	MLLW
H11299	2005-07-06	10000	North American Datum 1983	MLLW
H11300	2005-07-06	10000	North American Datum 1983	MLLW

Table A-1 – Continued

Survey ID	***Year***	***Scale/Vertical Accuracy***	***Original Vertical Datum***	***Provided Horizontal Datum***
H11723	2007-09-27	20000	North American Datum 1983	MLLW
H11723	2007-09-27	20000	North American Datum 1983	MLLW
H11723	2007-09-27	20000	North American Datum 1983	MLLW
H11723	2007-09-27	20000	North American Datum 1983	MLLW
H11724	2007-09-28	10000	North American Datum 1983	MLLW
H11724	2007-09-28	10000	North American Datum 1983	MLLW
H11724	2007-09-28	10000	North American Datum 1983	MLLW
H11724	2007-09-28	10000	North American Datum 1983	MLLW
H11724	2007-09-28	10000	North American Datum 1983	MLLW
H11724	2007-09-28	10000	North American Datum 1983	MLLW
H11724	2007-09-28	10000	North American Datum 1983	MLLW

Table A-1 – Continued

Survey ID	***Year***	***Scale/Vertical Accuracy***	***Original Vertical Datum***	***Provided Horizontal Datum***
H11724	2007-09-28	10000	North American Datum 1983	MLLW
H11724	2007-09-28	10000	North American Datum 1983	MLLW
H11724	2007-09-28	10000	North American Datum 1983	MLLW
H11724	2007-09-28	10000	North American Datum 1983	MLLW
H11725	2007-10-02	10000	North American Datum 1983	MLLW
H11725	2007-10-02	10000	North American Datum 1983	MLLW
H11726	2007-10-01	10000	North American Datum 1983	MLLW
H11726	2007-10-01	10000	North American Datum 1983	MLLW
H11726	2007-10-01	10000	North American Datum 1983	MLLW
H11757	2007-10-02	10000	North American Datum 1983	MLLW
H11927	2008-09-23	10000	North American Datum 1983	MLLW

Table A-1 – Continued

Survey ID	***Year***	***Scale/Vertical Accuracy***	***Original Vertical Datum***	***Provided Horizontal Datum***
H11927	2008-09-23	10000	North American Datum 1983	MLLW
H11927	2008-09-23	10000	North American Datum 1983	MLLW
H11939	2008-09-18	10000	North American Datum 1983	MLLW
H11939	2008-09-18	10000	North American Datum 1983	MLLW
H11939	2008-09-18	10000	North American Datum 1983	MLLW
H12122	2010-09-22	20000	North American Datum 1983	MLLW
H12122	2010-09-22	20000	North American Datum 1983	MLLW
H12122	2010-09-22	20000	North American Datum 1983	MLLW
H12122	2010-09-22	20000	North American Datum 1983	MLLW
H12123	2010-08-08	20000	North American Datum 1983	MLLW
H12123	2010-08-08	20000	North American Datum 1983	MLLW

Table A-1 – Continued

Survey ID	***Year***	***Scale/Vertical Accuracy***	***Original Vertical Datum***	***Provided Horizontal Datum***
H12123	2010-08-08	20000	North American Datum 1983	MLLW
H12123	2010-08-08	20000	North American Datum 1983	MLLW